



The Inanimate Enemy and the Corps

A New Realm of Activity

In bringing multiple harbors to the Texas Coast and in furnishing an imposing array of defensive works and wartime services, the army engineers had only tangentially dealt with a problem that would later become a prime concern. Their few forays into the arena of flood control were conducted initially under the semblance of preserving navigable waterways or of protecting federal military installations.

The first attempt to battle the forces of floodwaters within the territory of the future Galveston District began in 1877. Frequent flooding that changed the channel and encroached upon the banks of the Rio Grande seriously jeopardized historic Fort Brown. A rather futile project, funded with an appropriation of corresponding magnitude, was initiated. Several years later, Major Mansfield inherited the protection of Fort Brown along with the other coastal projects that comprised the work of the new Galveston Engineer Office. By 1882, he had concluded that it would be more expedient to move the endangered buildings on the post than to attempt to control the Rio Grande by artificial works.¹ So much for the first federal venture into flood control in Texas. At this point, and for a great many years to come, flood control per se was not considered a proper function of the federal government.

Sweeping reforms in the twentieth century would change all that. New forces were at work, redefining governmental responsibilities and offering fresh perspectives on national resources. Gradually, progressive legislation brought a fresh crop of functions into the federal domain.

Federal policy toward flood control evolved through several formative stages, in response to three critical legislative acts. The first, passed March 1, 1917, brought the subject of flood control out into the open and asserted that it was the proper business of the national government. The effect of this legislation on the Galveston District was largely to stimulate watershed studies on some of the "navigable" rivers that ranked among the greatest flooding offenders.²

Opposite page: Flooding on Galveston's Strand after 1919 storm produces a scene only too familiar to many communities throughout Texas.

The Rivers and Harbors Act of March 3, 1925 opened the door to a broader and more integrated approach to water resources development, calling for comprehensive planning that would incorporate navigational improvements, potential power production, flood control, and irrigation needs. The Corps of Engineers responded with House Document 308, Sixty-ninth Congress, First session, setting into motion an extensive series of preliminary examinations directed toward these ends with an emphasis on feasibility of power development.³ Only one river within the Galveston District boundaries was thought at the time to have power capabilities worth exploring; accordingly, a "308 report" on the Guadalupe River was prepared.

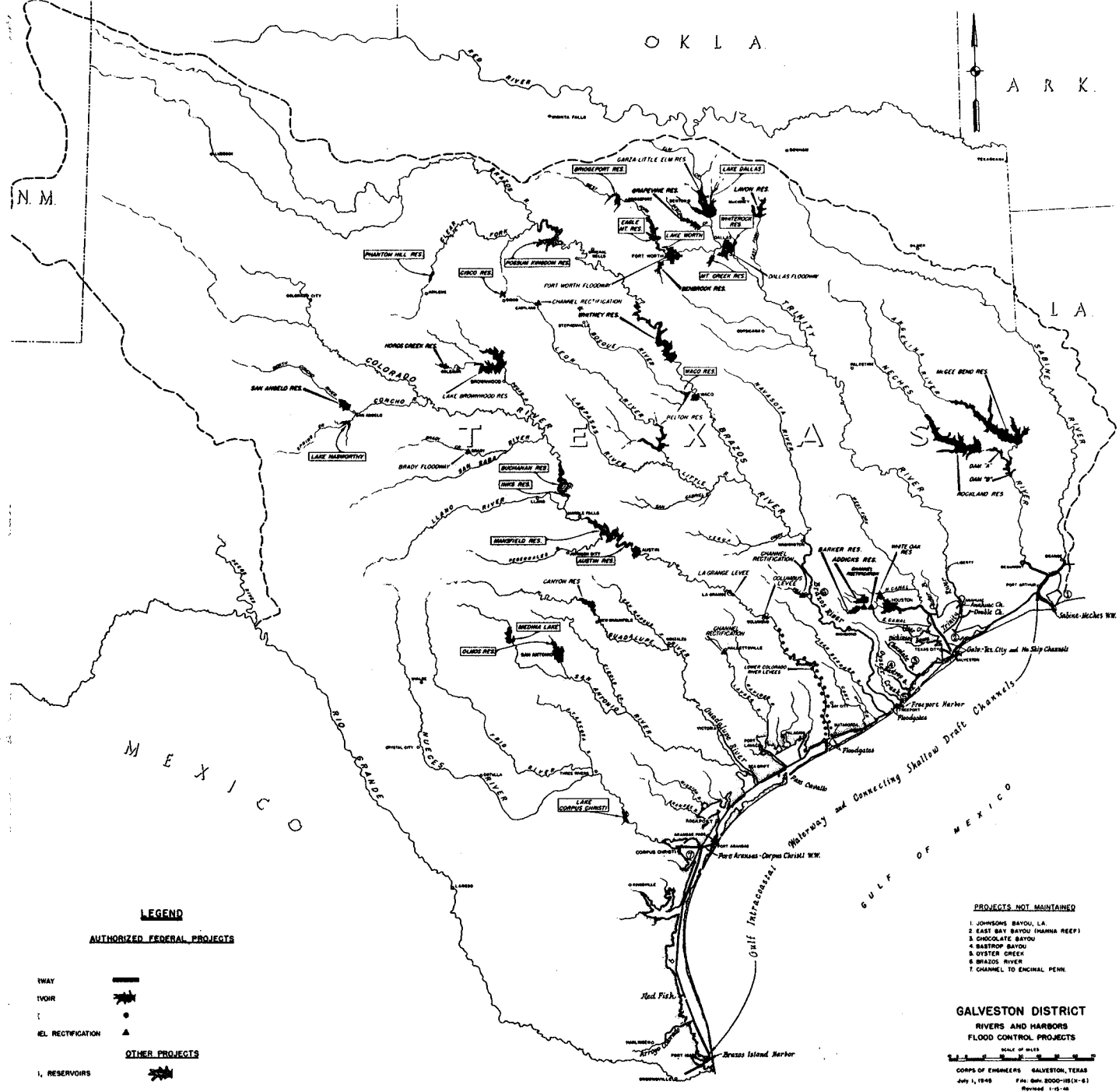
The real milestone in flood-control policy was reached with passage of the Flood Control Act of June 22, 1936, which declared:

. . . that investigations and improvements of rivers and other waterways, including watersheds thereof, for flood-control purposes are in the interest of the general welfare; [and] that the Federal Government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected.⁴

This act spelled out, in no uncertain terms, a new direction for flood-control work, not only justifying it as a proper activity of the federal government, but also extending its scope beyond the limitations of navigation. In Galveston, this legislation spurred a flurry of activity as the district viewed the many rivers and streams within its boundaries in a different light.

During the years between 1936 and 1941, the Galveston District conducted flood-control studies on sixteen river systems, including all the major rivers in Texas plus Santa Isabel Creek, the Pecos River, the Rio Grande in Colorado and New Mexico, and the Mimbres River in New Mexico. The tremendous increase in the volume of work sparked expansion of the district, producing an influx of personnel that included many engineers who remained to become mainstays in the Galveston District.

Boundary changes occurred also as flood-control work was taken up by the army engineers. Temporarily, the Brazos River above Washington was transferred in 1936 to the short-lived Mineral Wells District, only to be reincorporated into the Galveston District by September of the following year. With formation of the Albuquerque District late in 1941, reassignment of responsibility for drainage basins of the Pecos River and of



Flood-control projects in the Galveston District, 1948

the Rio Grande above the mouth of the Pecos removed a considerable area from Galveston's territory.⁵

Military priorities prompted by World War II interrupted the preoccupation with flood-control work. After the war, the return of peace brought renewed interest in civil works and the Corps picked up the threads of the flood-control efforts. On the basis of prewar studies and reports that had been submitted to Congress, eight projects had been authorized for construction in the Galveston District: Buffalo Bayou, Whitney Reservoir on the Brazos, and six projects on the Colorado River.



Houston city waterworks pumping plant submerged by 1935 flood

Help for the City of Houston

The first project was generated by a deluge in Houston that occurred December 6-8, 1935. Memories of another bad flood during May 24-31, 1929 still lingered in the minds of Houstonians. With a rainfall averaging 11.7 inches for the watershed, the 1935 storm produced an overflow of Buffalo Bayou and its tributaries resulting in loss of eight lives, damage in the city amounting to \$2.5 million, and increased currents along with silting in the Houston Ship Channel that restricted navigation for three days.⁶

Soon to become one of the fastest-growing cities in the country, Houston loomed as a superb candidate for even more devastation from floods. In its original state, the relatively flat terrain provided only low slopes to facilitate runoff following a rain. This limitation, coupled with the impervious clay strata characteristic of the watershed, made for slow drainage even before the settlement and urbanization of Houston began. Manifestations of the ensuing problem had been noted as early as 1835:

Although roads were a problem throughout Texas in wet weather, the Brazos prairie west of Houston became especially notorious . . . in bad weather much of it flooded, presenting so dismal a sight that many immigrants who intended to settle in Texas returned home after seeing it.⁷

Those stalwart pioneers, sturdy and stubborn enough to settle in Houston despite these disadvantages, planted seeds of urbanization. One hundred years later, the hallmarks of urban development — streets, highways, parking lots, and sidewalks — had seriously aggravated the situation, interfering with natural drainage by increasing the rate of runoff and, consequently, the potential of flood damage.

After the 1935 flood, Congress directed the chief of engineers to study the problem of Buffalo Bayou. Submitted by the Galveston District in April, 1937, the report of this study led to legislation in 1938 and 1939 authorizing a project to protect the city of Houston and its ship channel from the ravages of flooding.⁸ By 1940, a detailed plan had been drawn involving three detention reservoirs, channel rectification, and two diversion canals.

The term “rectification” as it is used by the army engineers refers to both straightening the channel alignment and enlarging the channel cross section to increase discharge capacity. Lining or paving the channel further serves to enhance flow capacity by reducing resistance or friction of the water against the banks, thus permitting faster runoff. Overall, the purpose is to lower the water surface in the channel.

As the project evolved under the 1940 plan, the essential ingredients actually constructed consisted of two detention dams upstream on Buffalo Bayou and rectification downstream. Barker and Addicks reservoirs were designed to control runoff from the westerly 279 square miles of the watershed. The earthen dams store large amounts of rain water and

Capitol Avenue bridge, looking upstream toward Sabine Street bridge in Houston after 1935 flood. Water has receded about 6 feet below crest.

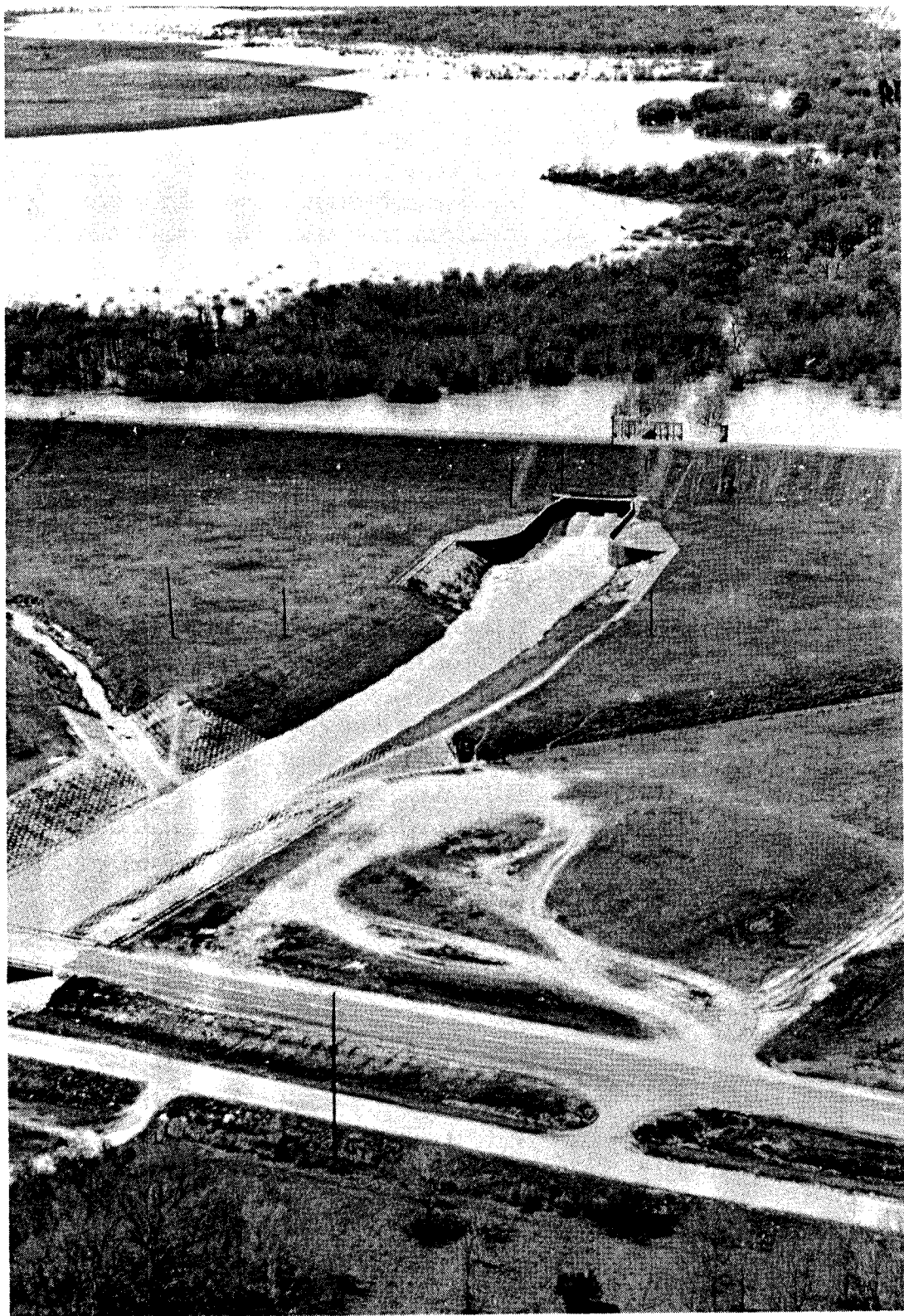




Barker Dam construction. Placing riprap at upstream end of outlet works, September 23, 1942

regulate release of the impounded waters through gated conduits. Contract work began on Barker Dam on February 2, 1942. Completed in 1945 at a cost of \$4,530,000, this structure extends a length of 13.6 miles with a reservoir capacity of 207,000 acre-feet. Addicks Dam, begun in 1946 and completed in 1948 at a cost of \$5,248,000, is 11.6 miles long and has storage capacity of 204,500 acre-feet.⁹

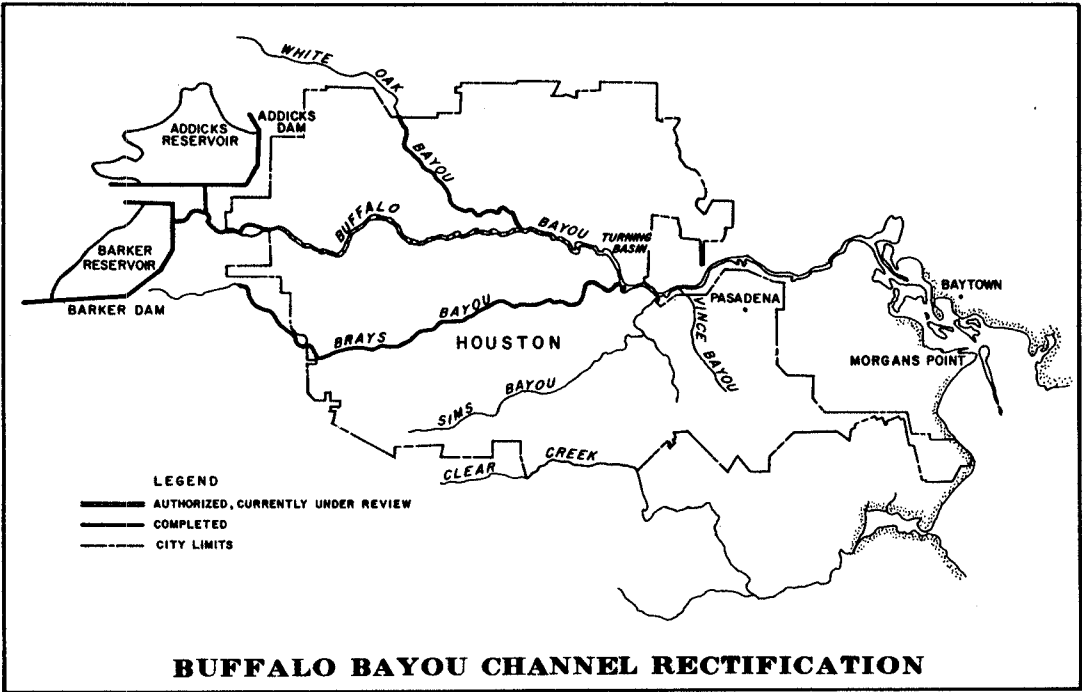
Other features of the original plan — diversion channels and a third reservoir on White Oak Bayou — were precluded by changes that took place during the war years. The tremendous industrial development along the ship channel and corresponding growth of the city, which over the decade of the 1940s represented a 54.6 percent population increase in Houston, made completion of the original flood-control plan impractical, if not impossible. The site selected for the White Oak Reservoir had been incorporated into the limits of the city and developed into a residential area. Similar developments covered considerable portions of the rights-of-way of the proposed diversion canals. The Galveston engineers returned to the drawing board to restudy the problem in 1948.¹⁰



Barker Dam outlet works and Reservoir, 1969

The problem of the Buffalo Bayou watershed did not then, and does not now, lend itself to simple solution. Initially, a “design storm” was developed from investigation of fifty-two storms that had occurred in central and coastal Texas. Serving as a measure for the magnitude of protection needed, the design storm was based largely upon a storm at Hearne in 1899 and incorporated some rainfall modifications based on a storm at Taylor in 1921. Local interests indicated they would be satisfied with protection against a lesser flood; consequently, the Corps of Engineers used the design storm for design of the reservoirs and the 1935 storm increased by 50 percent for design of the channels below the reservoirs.

By the time the engineers readdressed themselves to the Buffalo Bayou plan in 1948, more refined guidelines for project design were available. With added experience in flood control since 1940, the Corps of Engineers had developed the concepts of Standard Project Storm and Standard Project Flood. A Standard Project Storm is defined as the most severe combination of meteorological parameters considered reasonably characteristic of a particular drainage area. The Standard Project Storm for Buffalo Bayou was determined as having an average depth of 19 inches over 200 square miles in twenty-four hours. The Standard Project Flood, the runoff from the Standard Project Storm, provides a practical measure of specific flood potential. As such, it serves as a standard against which degree of protection may be judged and represents the flood discharge that should be selected as the design flood for a project.¹¹





Brays Bayou rectified channel, 1976

Once determined, any Standard Project Storm remains constant. The Standard Project Flood is variable, however, changing in relation to conditions within the watershed. Such has been the case in Houston, where the rapid rate of population growth and urban improvement has dramatically altered runoff conditions.

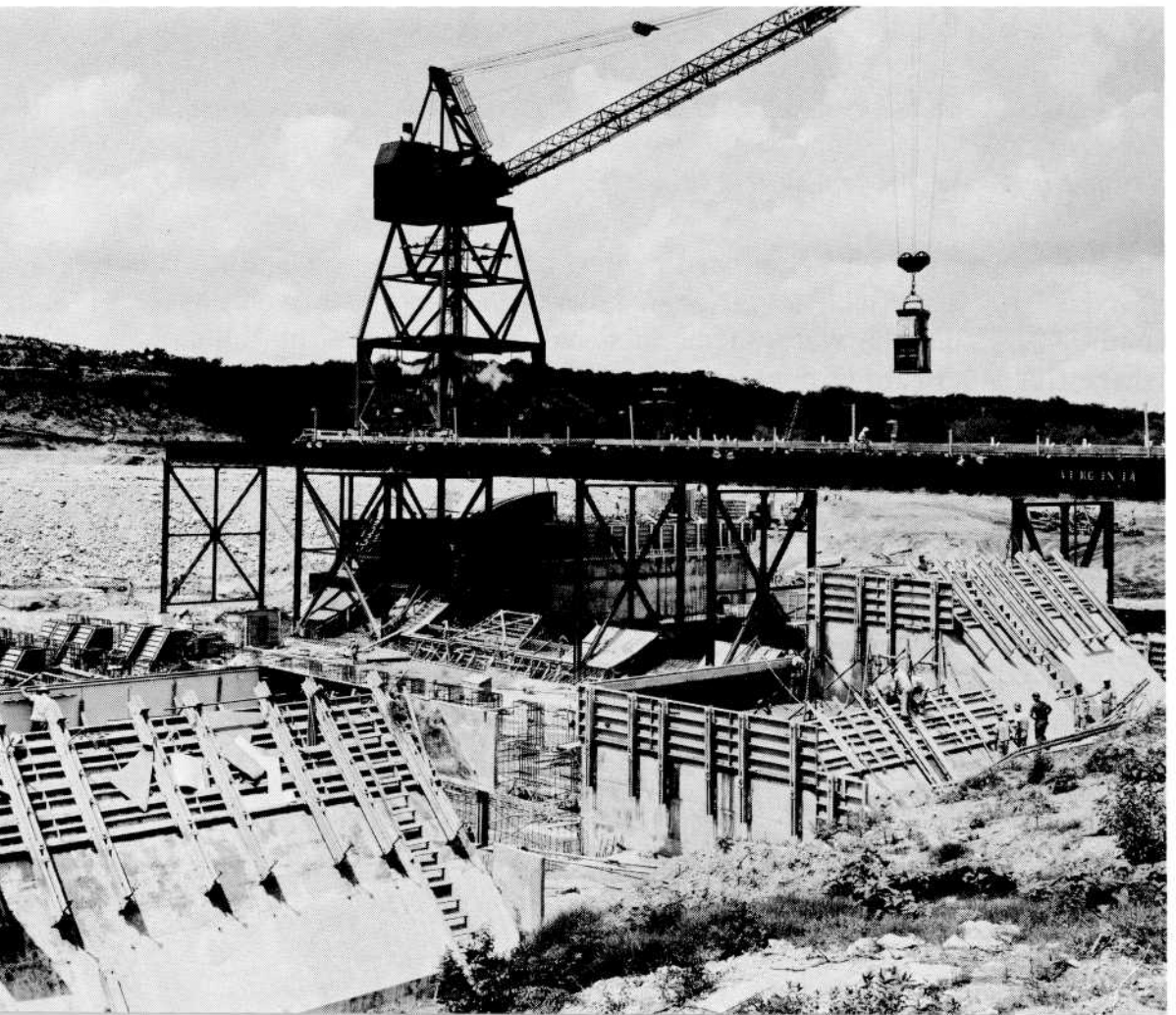
Using an updated Standard Project Flood, the Galveston engineers explored two basic plans. The plan calling for diversion of most of the floodwaters into the Brazos River watershed they rejected as infeasible on a number of counts. They settled on the alternate plan, rectification of the principal channels in the Buffalo Bayou watershed, to complete the project with sufficient capacity to carry the design flood and releases from the reservoirs across the city and into the ship channel. In 1954, Congress authorized channel work in Buffalo Bayou and two of its tributaries, Brays and White Oak bayous. An upstream extension on White Oak Bayou was authorized in 1965.¹²

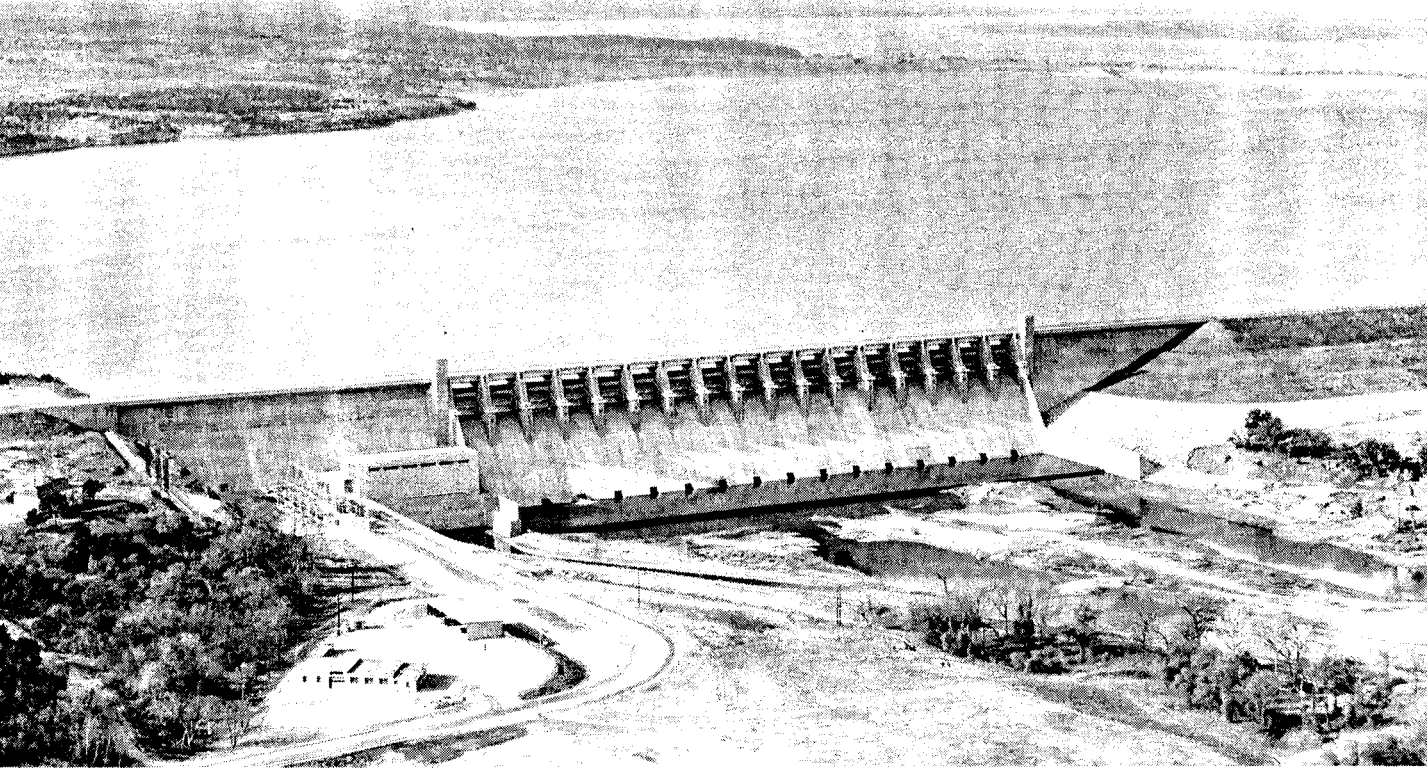
Rectification on Brays and White Oak bayous has been completed; however, only about 7 miles of discharge channel have been constructed on Buffalo Bayou below the reservoirs. Because the projected improvement downstream would involve substantial alteration of the natural state of the bayou, opposition arose which has deferred work on the project since the late 1960s. Meanwhile, the city continues to grow, the Standard Project Flood continues to increase, and the safety of the city of Houston from major flood damage remains a significant and unsolved question.

Flood Control, Fort Worth, and Flood Plain Management

The years immediately following World War II found Galveston District engineers busily engaged in flood-control projects throughout the state. By 1950, the district was working on eighteen authorized projects. Construction operations ranged from the San Angelo Dam and Reservoir on the North Concho River in West Texas, to the Whitney on the Brazos,

Whitney Dam construction, 1949. Buckets transport concrete to the forms.



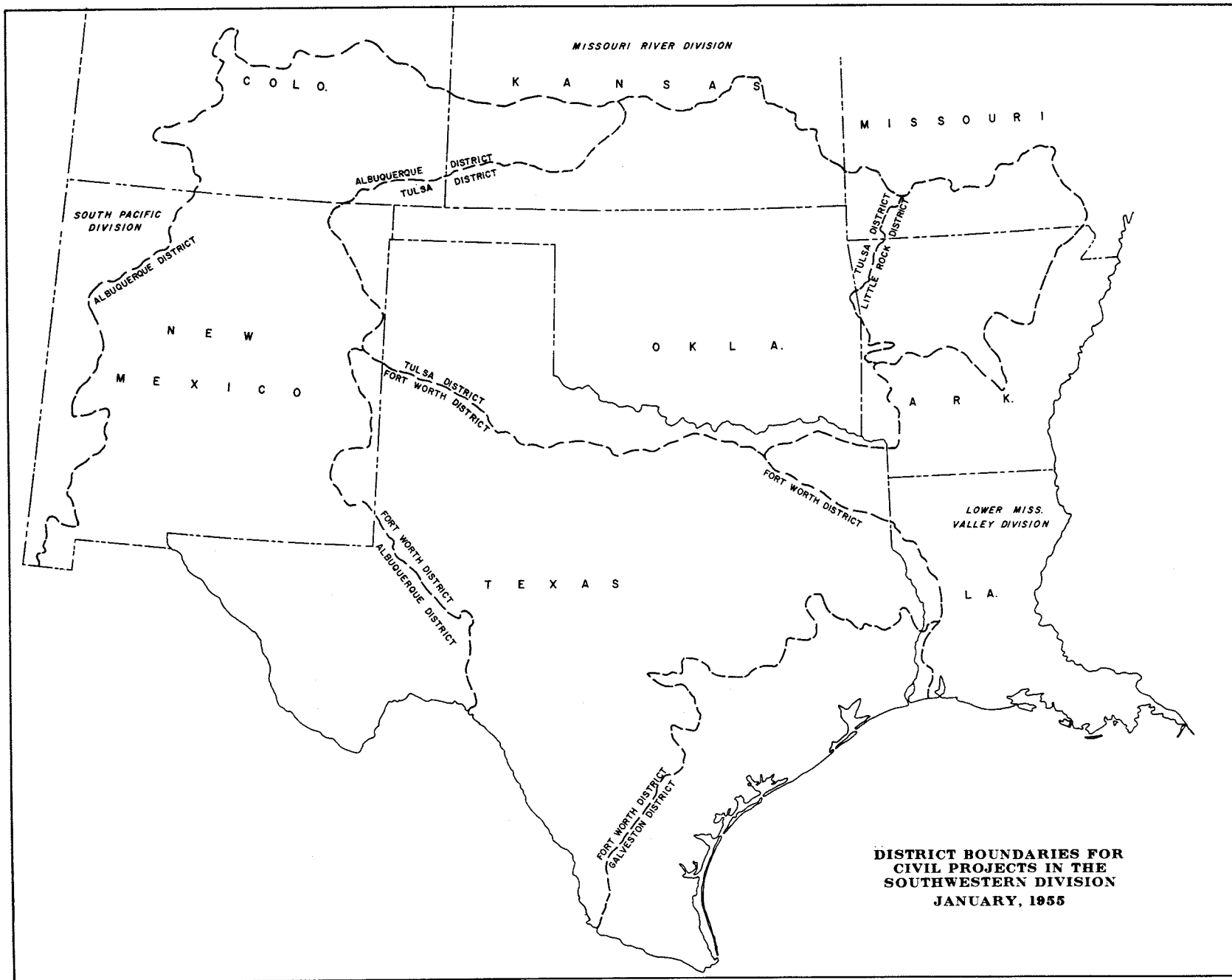


Whitney Dam and Reservoir on the Brazos River

to Dam B (later renamed Town Bluff) on the Neches River. Other projects underway during this period included levee repairs, floodways for Fort Worth and Dallas, and dams and reservoirs on the Trinity River (Grapevine, Benbrook, Lavon, and Garza-Little Elm); Belton Dam and Reservoir on the Leon River, a tributary of the Brazos; and Hords Creek Dam and Reservoir on Pecan Bayou, a tributary of the Colorado. Preconstruction planning had begun for Canyon Reservoir on the Guadalupe River.

Late in the 1940s, a move was afoot to streamline Corps operations; various organizational changes were considered. One economy measure adopted was reduction of the number of field offices, phasing out the installations at Harrisburg, Bay City, and Port Lavaca. A large Fort Worth suboffice had grown to handle projects on the Trinity River. As possible cost-cutting alternatives were being pondered, influential citizens in Fort Worth attempted to have the Galveston District moved to Fort Worth. For an uncomfortable time, the future of the Galveston District teetered precariously. Finally, on April 14, 1950, a second civil works district in Texas was established at Fort Worth.¹³

The original division of boundaries was based on function: flood control and water conservation and utilization were assigned to the new Fort Worth District; responsibility for navigation and major drainage projects along the coastal plain was retained by the Galveston District. Thus, the many flood-control projects authorized and initiated by the Galveston



**DISTRICT BOUNDARIES FOR
CIVIL PROJECTS IN THE
SOUTHWESTERN DIVISION
JANUARY, 1955**

District were transferred to Fort Worth and completed under that district's jurisdiction.

By January 7, 1955, civil works boundaries for the two districts in Texas were redefined, this time on a geographic basis, restoring full functional responsibility to Galveston for all drainage basins within the coastal area extending roughly an average of 100 miles inland. Resuming its flood-control activities, the Galveston District completed works consisting of levees and channel rectification at San Diego Creek near Alice in July, 1955; at Little Cypress Bayou near Orange in April, 1956; and at Tranquitas Creek near Kingsville in October of that year. Work also began on improvement of the Lavaca River near Hallettsville, completed in September of 1960.¹⁴ Projects authorized later, which are now under construction, include diversion and rectification works for Highland Bayou to protect the cities of Hitchcock and La Marque in Galveston County, and channel rectification plus a velocity control structure to reduce erosion on Vince Bayou, a tributary of the Houston Ship Channel at Pasadena.

As the Corps gained experience in flood-control work, the limitations of structural improvement alone became apparent. Dams, levees, floodwalls, and channel rectification could not keep pace with the rapid rate of urban development in flood-prone areas. New approaches to the growing problems associated with flood plains were clearly needed.

Legislation passed in 1960 introduced a new function for the army engineers.¹⁵ Flood plain management presented an alternative to augment traditional techniques for fighting flood hazards. Rather than building structures to protect existing developments from flooding, flood plain management attempted to preserve the integrity of the flood plain by preventing construction of buildings on the river's right-of-way. For the Corps of Engineers, this meant compiling and disseminating information on floods and flood damages in vulnerable localities to help local agencies regulate land use and protect existing structures on the flood plain.

In highly developed areas such as Houston, flood plain management had limited applicability, but in less urbanized locations it offered a useful preventive approach. The Galveston District initiated flood plain management services in 1967, responding first to a request made through the Texas Water Development Board to study Dickinson Bayou in Galveston County. A Flood Plain Information Report on Dickinson Bayou was prepared and made available to the requesting agencies, Galveston County and its Water Control and Improvement District No. 1, to assist them in taking appropriate steps to reduce flood hazards and resulting damage.

In 1969, Flood Plain Management Services became a full-fledged branch in the Engineering Division of the Galveston District. To date, this

branch has completed thirty flood plain information reports. These reports generate data that serve as guidelines to the local communities requesting them. A typical report contains maps of the flooded area, flood profiles, charts, tables, photographs, and a narrative describing former floods and projecting the characteristics of those that may be expected in the future. Another service performed by the branch has been to search existing files and furnish to individuals information regarding the flood potential of their private property.

Meanwhile, federal involvement in the problems related to flooding had been growing. The National Flood Insurance Act of 1968 authorized a government-sponsored flood insurance program to be conducted under the direction of the Department of Housing and Urban Development (HUD).¹⁶ This created an additional program in the Flood Plain Management Services Branch. At the request of HUD, the army engineers study specified locales, identifying those areas subject to inundation. HUD uses this information in setting the premium rates for the federally subsidized flood insurance. Since 1969, the Galveston District has prepared fourteen flood insurance studies for the Federal Insurance Administration of HUD. At present, the district is conducting four studies in Orange County and a large-scale study of Harris County, which will result in thirty-one separate reports covering all incorporated and unincorporated areas of the county.

In large measure, the multifaceted flood plain management program has placed the Corps of Engineers in an advisory capacity to municipal governments and other public agencies. The army engineers further assist these local groups upon request by interpreting flood information pertinent to future land use, providing guidance on proper building and site planning, and evaluating the effects of urban encroachment on the flood plain. Flood plain regulations — land-use controls designed to direct flood plain development so as to lessen the damaging effects of floods — fall under the jurisdiction of state and local governments.

Protection against the Sea

With the expertise the Corps was developing in the general realm of flood control, it was not surprising that the Galveston engineers were soon called upon to furnish protection against floods generated by high tides accompanying tropical storms. These storms assault the Texas Coast with an average frequency of once every two years. The first locality to enlist Corps aid in safeguarding against hurricane flooding was highly industrialized Texas City, situated on the southwest shore of Galveston Bay.



Workmen at railroad opening of closure structure in Texas City floodwall, 1975

A preliminary examination to explore the feasibility of furnishing such protection to Texas City and vicinity was authorized in 1948. At that time, local protective works consisted of a concrete seawall extending along a portion of the bay with earth levees adjoining each end and extending inland. This existing system would not prevent storm tides higher than 5 feet from inundating the ground behind it. Further, withdrawal of ground water had caused subsidence, lowering the height of the seawall from 12.6 feet to 11 feet in some places and increasing the area's vulnerability to severe flooding. The value of residential, business, and industrial development in Texas City was estimated at about \$180 million in 1949.¹⁷

This value had escalated to \$518 million by 1956, the year Galveston County furnished assurances of local participation and the Galveston District submitted a favorable survey report to the chief of engineers. Two years later, Congress authorized a project providing for improvement of the existing seawall, concrete floodwalls through the industrial area, levees extending inland on the north and south sides of the city, drainage and closure structures, a tide and navigation opening at Moses Lake, highway ramps, and two pumping plants. Setting a precedent for future hurricane-flood protection projects, local participation consisted of 30 percent of the first cost including cost of land, easements, and rights-of-way.¹⁸

In September of 1960, the chief of engineers authorized modification of the plan, adding 1.8 miles of levee that would partially encircle and protect the city of La Marque. Taking off toward the northwest in an angle from the original project alignment, this extension became dubbed the "dogleg."¹⁹

The next significant influence on the project design intruded one year later. Hurricane Carla presented more extreme parameters than had been anticipated for the design storm that might be expected to occur once in a hundred years. Reviewing the problem of waves overtopping the levees, the army engineers raised the height of the proposed floodwalls and levees from 18 feet to 23 feet along the bay shore to thwart a new design tide of 15 feet above mean sea level. They also found that the foundation below the existing seawall was not suitable for the increased alterations required and revised the plans to provide instead levee protection about 1,500 feet seaward in Galveston Bay.²⁰

In mid-1962, the general location of the features proposed for construction was presented at a public meeting. The two hundred interested people gathered at the meeting responded favorably. A proposal made at that time suggested extending the project to include all of La Marque and Hitchcock. This proposal was reiterated in the form of a request by the Galveston County Commissioners Court at a meeting held in Hitchcock on January 8, 1963. It was studied by the Corps of Engineers and subsequently authorized by Congress in 1968. The La Marque-Hitchcock extension as planned would extend southeast along the Gulf Freeway (IH 45), turn south and then west across Jones Bay, and proceed inland to high ground near Hitchcock. In the course of protecting a larger area, it would eliminate the need for the "dogleg" levee and the pumping station at La Marque.²¹

Construction of the Texas City project began in April of 1962 on the levees around Moses Lake. The tide control structure, with an overhead gate that can be lowered against a rising tide into a navigation opening, 12 feet deep by 56 feet wide, was completed in 1967; the Texas City pumping station, with a capacity of 450,000 gallons per minute, was completed in 1968.²²

Desiring protection during the interim while the enlarged project would be under construction, Galveston County built most of the length of the original dogleg levee during the early 1970s; however, this levee was constructed only to an elevation of 10 feet above mean sea level — less than the height of the authorized project design. In June, 1974, the county withdrew local sponsorship from the La Marque-Hitchcock extension because of environmental problems associated with crossing Jones Bay and blocking off marshlands.²³ This turn of events restored the permanent need for the dogleg, which will be lengthened and raised to specified

project dimensions by the Galveston District engineers, and for the La Marque pumping station which remains to be designed and constructed. These final features of the project are scheduled for completion in 1980.

Estimated to cost over \$40 million, the Texas City project will safeguard 36 square miles of valuable residential and commercial developments, petrochemical plants, oil refineries, and port and railroad terminals. The protective system stretching along 15.7 miles of earthen levees and 1.3 miles of floodwalls and closure structures will fortify this vital area against a 15-foot storm tide.

Texas City floodwall, photographed here in 1975, fortifies valuable industrial property against overflows from the harbor.



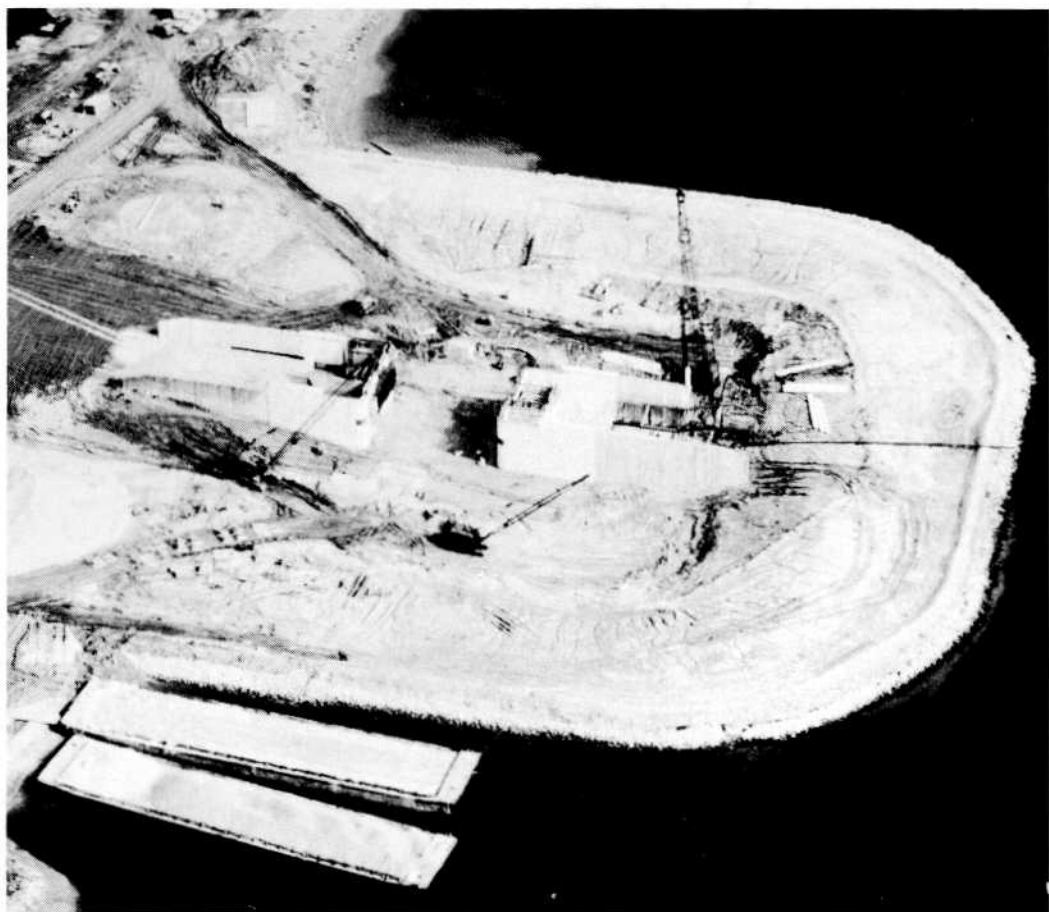
While the Texas City project was still in its infancy, the Corps of Engineers began addressing itself to the problems of hurricanes on another level. In 1955, Congress called for examination of "coastal and tidal areas of the eastern and southern United States . . . where severe damages have occurred from hurricane winds and tides." Public Law 71, enacted by the Eighty-fourth Congress, contained broad study authority for investigations into:

. . . behavior and frequency of hurricanes, . . . determination of methods of forecasting their paths and improving warning services, . . . of possible means of preventing loss of human lives and damages to property, with due consideration of the economics of proposed breakwaters, seawalls, dikes, dams, and other structures, warning services, or other measures²⁴

Under this authority, the Galveston District first examined individual locations along the Texas Coast with an eye toward localized protection. These studies led to legislation in 1962 providing for hurricane-flood protection projects at Freeport and at Port Arthur.

Freeport hurricane-flood protection. Cofferdam for tidegate construction in early stages, November, 1975

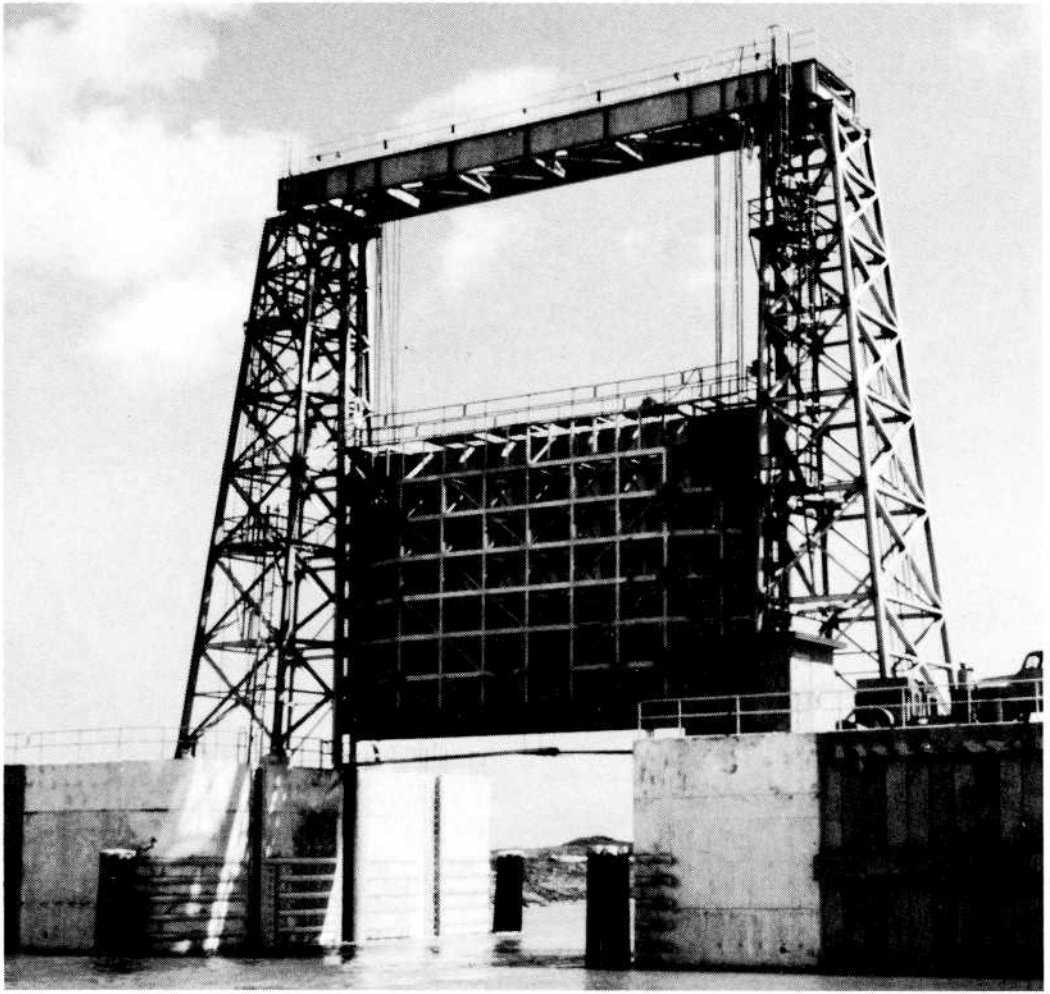




Freeport tidegate construction, December, 1976

Both areas had local levee systems, but Hurricane Carla had demonstrated their inadequacies. The newer federal projects were designed to improve and augment existing protection. At Freeport, about 42 square miles (including areas of Freeport, Velasco, Lake Jackson, Clute, Lake Barbara, and Oyster Creek) will be protected by approximately 56 miles of levees, wave barriers, floodwalls, drainage structures, pumping plants, and a vertical lift tide gate. Spanning the Old River just above the federal navigation project, this structure, slated for completion by 1978, will have a navigation opening 61.4 feet high and 75 feet wide.

At Port Arthur, approximately 60 square miles will be fortified against floodwaters by some 35 miles of protective works: 28 miles of earthen levees, 7 miles of floodwalls, vehicular and railroad closure structures, street and highway ramps, and an elaborate system to handle interior drainage consisting of gated gravity drainage structures and pumping plants. The largest of these, a pumping station to be erected on Alligator Bayou, will have a capacity of 2,250,000 gallons per minute.



Texas City tidegate at entrance to Moses Lake

Meanwhile, Hurricane Carla added impetus to the studies of coastal protection. A vastly more comprehensive investigation, known as the Texas Coast Hurricane Studies, was undertaken in 1964 in view of the fact that accelerating development along the coast was increasing potential for hurricane-flood damages faster than protection could be provided through local measures.²⁵

Still underway, these broader studies have yielded much valuable information. Identification of flood-prone areas along the entire length of the Texas coastline for storms of various frequencies has been useful for the federal insurance program and future flood plain management. The studies have generated a wealth of data regarding storm surges, waves, winds, and foundation conditions. Sophisticated mathematical models devised to estimate storm surges represent significant technical improvements in storm prediction. Concepts for design of comprehensive

structural protection and a number of plans, feasible in terms of both engineering and economic considerations, have been developed.

Through the many public meetings that have been held and speeches that have been delivered in conjunction with the coastal hurricane studies, the Galveston District hopes to have increased public awareness of flooding potential. The history of this region shows clearly the dangers of the apathy that tends to build up as intervals between storms lengthen.

A beneficial spin-off from these studies is the tide gauge network installed to collect storm data. Galveston engineers placed water level recording gauges not only along the open coast, but also in the bays and estuaries. This system allowed far more inclusive measurement than had been possible previously. Although data for the study have been obtained, forty-two gauges remain stationed along the coast, continuously monitoring tidal fluctuations. The district makes available the more complete information afforded by this network to industrial, local, state, and federal agencies for purposes of navigation, environmental conservation, boundary determinations, and special research studies.

The latest adversary in the fight against tidal flooding has advanced in the form of land subsidence, a condition resulting from heavy withdrawal of subsurface water. With removal of ground water and corresponding reduction of the water level, pressure drops between clay strata, causing the clay to release its water and become compressed, much like a sponge being squeezed. Unlike the sponge, however, the clay will not spring back to its previous dimensions and the elevation of the land above it will remain irreversibly depressed.

Recently, the problem of land subsidence has plagued many of the heavily populated and highly industrialized areas lining Galveston Bay and the Houston Ship Channel. Through its role of studying and providing protection against flooding, the Corps of Engineers has encountered subsidence as an aggravating factor, but one over which it exercises no control since subsurface water withdrawal is regulated by state and local authorities.

In 1968, the particularly acute problem in residential portions of Baytown adjoining Burnett, Crystal, and Scott bays launched the first study by the Corps of Engineers to investigate flooding specifically due to subsidence.²⁶ Geological investigations showed surface elevations in Baytown had subsided as much as 8.2 feet during the years from 1920 to 1973. If groundwater withdrawals were limited immediately, yet another 1.4 feet of subsidence would occur; if limited by the year 1980, an estimated 2.6 feet of subsidence would be anticipated. Should withdrawals continue at present rates, which cause decreased water pressures in the



Subsidence at Baytown. Rate of subsidence is striking in case of house shown above in November, 1973 and below in December, 1975.



aquifers, subsidence amounting to an additional 6.4 feet may be expected by 1995. The significance of these projections of future subsidence lies in the fact that homes now located at reasonably safe elevations will quickly become subject to disastrous flooding as subsidence continues.²⁷

To conduct this unique study, the Galveston engineers applied technical, economic, environmental, and social criteria to the various alternatives that might offer relief to the Baytown dilemma. The most feasible solution — in fact, the only feasible solution — is without precedent. It consists of a permanent evacuation plan under which 448 families, roughly 1,550 residents, in the 750-acre area comprising the fifty-year flood plain would be relocated with federal assistance provided by Public Law 91-646, the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970. Vacated structures would be demolished and the land would be transferred to the city for uses consistent with the objective to reduce flood damage. Projected use of the land would assume conversion into a recreational area for public enjoyment and an improved habitat for birds and small animals.²⁸

Implementation of this plan remains to be seen.²⁹ Meanwhile, Galveston District engineers continue to work with these communities and others like them, ever seeking new ways to reduce losses and alleviate human suffering caused by man's age-old adversary — nature.

Notes to Chapter 8

¹ *Annual Report of the Chief of Engineers to the Secretary of War for the Year 1882* (Washington, D.C.: Government Printing Office, 1882), p. 201 (hereafter cited as *ARCE*, followed by date of fiscal year covered in report).

² 33 U.S.C.A. §§ 701-703 (1970); e.g., the Colorado River study in H.R. Doc. 304, 66th Cong., 1st sess. (1919).

³ Ch. 467, 43 Stat. 1186; H.R. Doc. 308, 69th Cong., 1st sess. (1926).

⁴ Ch. 688, § 1, 49 Stat. 1570.

⁵ The Mineral Wells District, established 1 April 1936 and discontinued 1 September 1937, was created specifically to construct a dam and reservoir at Possum Kingdom Bend on the Brazos. This project was turned over to the Texas Works Progress Administration on 27 August 1937, to be conducted under provisions of the Emergency Relief Act of 1935. *ARCE*, 1938, p. 893; Office of the Chief of Engineers (OCE), General Order (GO) 3, 23 March 1936; OCE, GO 11, 10 August 1937; OCE, GO 14, 23 December 1941.

⁶ H.R. Doc. 250, 83d Cong., 2d sess. (1953), p. 4; Ellsworth I. Davis, "Development of a Flood Control Plan for Houston, Tex.," *Transactions of the American Society of Civil Engineers* 118 (1953): 892 (hereafter cited as Davis, "Flood Control Plan").

⁷ Marilyn McAdams Sibley, *The Port of Houston* (Austin and London: University of Texas Press, 1968), p. 61.

⁸ Rivers and Harbors Act of June 20, 1938, ch. 535, 52 Stat. 802; Flood Control Act of August 11, 1939, ch. 699, § 32, 53 Stat. 1414, modified terms of local cooperation.

⁹ *ARCE*, 1942, p. 913; An acre-foot equals 1 acre of land covered with water 1 foot deep, or 325,850 gallons; *Reservoir Regulations Manual for Addicks and Barker Reservoirs* (Galveston: Corps of Engineers, 1962), table 1 (R 1-64).

¹⁰ H.R. Doc. 250, 83d Cong., 2d sess. (1953), p. 3; Davis, "Flood Control Plan," pp. 894-95.

¹¹ Davis, "Flood Control Plan," p. 895.

¹² *Ibid.*, pp. 897-99; Flood Control Act of September 3, 1954, ch. 1264, § 203, 68 Stat. 1248; Flood Control Act of October 27, 1965, Pub. L. No. 89-298, § 204, 79 Stat. 1073.

¹³ OCE, GO 4, 14 April 1950.

¹⁴ OCE, GO 1, 7 January 1955; *ARCE*, 1959, p. 726; *ARCE*, 1961, p. 787.

¹⁵ Flood Control Act of July 14, 1960, Pub. L. No. 86-645, §§ 206-208, 74 Stat. 480.

¹⁶ National Flood Insurance Act of August 1, 1968, Pub. L. No. 90-448, 82 Stat. 572 (codified in scattered sections of 42 U.S.C.A.).

¹⁷ Flood Control Act of June 30, 1948, ch. 771, 62 Stat. 1171; Thomas W. Anderson, "History-Progress-Future Plans for the Texas City-La Marque-Hitchcock Hurricane-Flood Protection Project" (Remarks before the Texas City Refinery Supervisors, 16 August 1973), pp. 1-3 (hereafter cited as Anderson Remarks).

¹⁸ H.R. Doc. 347, 85th Cong., 2d sess. (1958), pp. 9-10; Anderson Remarks, pp. 3-4; Flood Control Act of July 3, 1958, Pub. L. No. 85-500, 72 Stat. 297.

¹⁹ Anderson Remarks, p. 4.

²⁰ *Ibid.*, p. 5.

²¹ *Ibid.*, p. 7; Flood Control Act of August 13, 1968, Pub. L. No. 90-483, 82 Stat. 731.

²² Anderson Remarks, pp. 6, 8.

²³ *Ibid.*, p. 9; *Galveston Daily News*, 4 June 1974.

²⁴ Act of June 15, 1955, ch. 140, 69 Stat. 132.

²⁵ Chester L. Pawlik, John W. Keith, and Jack H. Armstrong, "Texas Coast Hurricane Flood Protection Studies," *Journal of the Hydraulics Division, ASCE* 93 (November 1967): 148-49.

²⁶ Flood Control Act of August 13, 1968, Pub. L. No. 90-483, 82 Stat. 731.

^{27.} *Burnett, Crystal, and Scott Bays and Vicinity, Baytown, Texas: Feasibility Report* (Galveston: Corps of Engineers, 1975), pp. 15-16.

^{28.} *Ibid.*, pp. 36, 53-61, 65.

^{29.} The Water Resources Development Act of 1976 authorized this project for Burnett, Crystal, and Scott bays.